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Designing Environmental Indicator Systems for Public Decisions

James M. McElfish, Jr. and Lyle M. Varnell*

INTRODUCTION

Government agencies and academic scientists have developed reliable sets of environmental indicators to assist in making decisions. This very recent trend has been driven in part by scientific advances that make it possible to construct indicators that are both rigorous and informative, and in part by policies that seek to justify environmental expenditures as likely to produce the beneficial results that they intend. Environmental indicators offer

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the promise of applying science to help decisionmakers select tools that will produce predictable outcomes in measurable ways. In this article we examine a specific element of the emerging environmental indicator model: the connection of the indicator with the decisionmaker. Although most research programs have assumed that if indicators are scientifically valid, public decisionmakers will use them to make better decisions, this assumption is not always justified.

Based on research in the middle-Atlantic region of the United States, we examine factors that affect the use of environmental indicators by public decisionmakers. In Part I, we begin with a brief history of environmental indicator development in the 1990s, discussing the genesis of numerous attempts to establish environmental indicators as part of the decisional framework and summarizing the threshold conclusions drawn by research on environmental indicator design. This research emphasizes scientific rigor, reproducibility, and interpretation, but less attention has been paid to the needs and characteristics of indicator users. In Part II we examine the potential users of environmental indicators. We find that critical factors potentially affecting indicator utility include the degree to which the indicator conforms to an identified management purpose, its conformity with jurisdictional and legal constraints on the intended user, and the manner in which data are maintained and conveyed for use. We conclude that in order to increase their effectiveness, environmental indicator systems must be: (1) designed to support the institutional characteristics and decisional needs of the users, (2) scaled geographically to the decisions they are intended to inform, and (3) institutionally maintained and transmitted in a manner that provides an endorsement of their credibility for the purposes for which they are to be used. Finally, in Part III we note the importance of institutional design in constructing systems of indicators to meet the needs of current decisionmakers, and we identify a new purpose for indicators in designing new institutional structures for environmental resource management.

I. HISTORY OF ENVIRONMENTAL INDICATOR DEVELOPMENT

The term "environmental indicators" encompasses all types of *numerical* measures of environmental conditions. These include, but are not limited to, indicators of pollutant loads and concentrations, landscape cover types and percentages, and indices of biological integrity. While a few environmental indicators, such as state water quality standards and national ambient air quality standards,[1] have long been integral to decisions under U.S. environmental laws, most government decisions affecting the environment have not relied on indicators. Nor have many decisionmakers had access to indicators that could inform their decisions. Often, available data were not sufficient to answer management questions on any scale larger than an individual permit decision, and typically did not address issues of ecosystem health or landscape resiliency. Beginning in the early 1990s, government scientists and agency managers began to seek systems that could generate and support this information.

A. Federal and State Environmental Indicator Projects

Several government-backed efforts were launched in the 1990s to tie environmental decisions more closely to measurable environmental data. Investments in the development of environmental indicators came about as the public began to seek more information about results of environmental programs, and as governmental program managers called for new metrics to evaluate progress that would expand on the use of process measures: *e.g.* permits issued, fines collected, or inspections conducted. A number of these investments were focused on identifying indicators of aquatic ecosystem conditions and the health of watershed lands for use in land management and regulatory decisions.[2]

Among the early experiments that used environmental indicators to guide strategic planning were the "comparative risk" projects launched by the Environmental Protection Agency (EPA) in several states in the early 1990s.[3] These short-term, state-focused projects were an outgrowth of a 1990 report by EPA's Science Advisory Board recommending that the federal agency reorder its priorities

1. *See* Water Quality Standards and Implementation Plans, 33 U.S.C. § 1313 (2000); National Primary and Secondary Ambient Air Quality Standards, 42 U.S.C. § 7409 (2005).

2. *See* DONNA MARIE BILKOVIC, CURRENT RESEARCH IN THE ASSESSMENT OF THE CONDITION AND INTEGRITY OF AN AQUATIC ECOSYSTEM: A BIBLIOGRAPHY (2001), *available at* http://ccrm.vims.edu/WatershedFinal.pdf (providing a very thorough annotated compendium of environmental indicators projects relating to aquatic ecosystems).

3. *See, e.g.*, THE OHIO COMPARATIVE RISK PROGRAM, OHIO ENVTL. PROT. AGENCY, OHIO STATE OF THE ENVIRONMENT REPORT 1995 (Heidi Hutchinson ed., 1995), *available at* http://www. pepps.fsu.edu/segip/states/OH/home.html.

and "attach as much importance to reducing ecological risk as it does to reducing human health risk."[4] EPA enlisted state agencies and academic institutions to identify risks to environmental resources and ways of measuring these risks to allow for a re-prioritization of government programs to protect the environment.

The National Environmental Performance Partnership Systems (NEPPS) program, launched by EPA and the Environmental Council of the States in 1995, also stimulated demand for environmental indicators. NEPPS attempts to provide the states with greater flexibility in setting priorities and with more accountability for achieving environmental results.[5] States participating in this voluntary program are eligible for EPA grants to advance state environmental goals.[6] Participating states develop Performance Partnership Agreements with their regional EPA offices.[7] The agreements must prioritize environmental issues, focus resources on agreed priorities, establish goals and milestones, and identify *indicators* that will be used to track progress.[8] The NEPPS program required states to monitor and report on a set of "core performance measures" and specifically allowed states to develop additional environmental indicators.[9] In order to assist the states, EPA funded the compilation of indicators that may be used in such agreements.[10]

Some states launched their own environmental indicator development projects to serve the needs of the NEPPS program. New Jersey, for example, created a results-based management system based on a comprehensive set of environmental indicators that were developed by the New Jersey Department of

4. Press Release, U.S. Envtl. Prot. Agency, Reducing Risk: Setting Priorities and Strategies for Envtl. Prot.: Chapter One Executive Summary (Sept. 26, 1990), *available at* http://www.epa.gov/ history/topics/risk/01.htm.

5. U.S. Envtl. Prot. Agency, National Environmental Performance Partnership System, http://www.epa.gov/ocirpage/nepps (last visited Feb. 3, 2006).

6. *Id.*

7. U.S. Envtl. Prot. Agency, Basic Information About Performance Partnerships, http://www.epa.gov/ocirpage/nepps/about.htm (last visited Feb. 3, 2006).

8. STATE ENVTL. GOALS AND INDICATORS PROJECT, FLA. CTR. FOR PUB. MGMT., PROSPECTIVE INDICATORS FOR STATE USE IN PERFORMANCE AGREEMENTS (1995), *available at* http://www.pepps.fsu.edu/segip/products/perform_agree.

9. U.S. Envtl. Prot. Agency, Joint Statement on Measuring Progress Under the National Environmental Performance Partnership System (Aug. 14, 1997), *available at* http://www.epa.gov/ ocirpage/nepps/pdf/joint_stmt_on_measuring.pdf.

10. STATE ENVTL. GOALS AND INDICATORS PROJECT, FLA. CTR. FOR PUB. MGMT., *supra* note 8.

Environmental Protection in collaboration with Rutgers University's New Jersey Center for Environmental Indicators.[11]

EPA also supported scientific research programs aimed at developing ecological indicators. These include the Environmental Monitoring and Assessment Program (EMAP), a long term research effort launched by EPA's Office of Research and Development in the late 1980s.[12] EMAP now encompasses a variety of component programs including EMAP West, EMAP's National Coastal Assessment, Aquatic Resource Monitoring, EMAP's Landscape Ecology Working Group, the Multi-Resolution Land Characteristics Interagency Consortium, Regional EMAP, the Mid-Atlantic Integrated Assessment (MAIA), the Estuarine and Great Lakes (EAGLES) Program, and EPA's recent national Ecological Indicator Development effort.[13]

Because indicators may vary by region, a geographic focus can strengthen the robustness of suites of indicators. EPA supported a series of regional research projects, including several in the middle-Atlantic states. In 1995, EPA established the Mid-Atlantic Integrated Assessment (MAIA), whose mission is "to transfer research, monitoring, and assessment innovations to managers in the Mid-Atlantic Region."[14] A related EMAP project produced a detailed regional landscape assessment using indicators of land cover, fragmentation, population, roads, streams, and other measures.[15] EPA's Regional Vulnerability Assessment Program (ReVA) is another regional science-based program focused on defining ecological indicators of stress and threat.[16] It is intended to

11. N.J. Ctr. for Envtl. Indicators, About Us, http://scc.rutgers.edu/cei/about/about_index.htm (last visited Feb. 3, 2006).

12. U.S. ENVTL. PROT. AGENCY, ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM (EMAP) RESEARCH STRATEGY (2002), *available at* http://www.epa.gov/emap/html/pubs/docs/resdocs/EMAP_Research_Strategy.pdf; *see* THE ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM: ECOLOGICAL INDICATORS (C.T. Hunsaker & D.E. Carpenter eds., 1990), EPA 600-3-90-060 (providing the suite of indicators for EMAP).

13. U.S. Envtl. Prot. Agency, Environmental Monitoring and Assessment Program (EMAP), Components, http://www.epa.gov/emap/html/component.html (last visited Feb. 3, 2006).

14. U.S. Envtl. Prot. Agency, About the Mid-Atlantic Integrated Assessment (MAIA), http://www.epa.gov/maia/html/about.html (last visited Feb. 3, 2006).

15. K. BRUCE JONES ET AL., AN ECOLOGICAL ASSESSMENT OF THE UNITED STATES MID-ATLANTIC REGION: A LANDSCAPE ATLAS (1997), EPA 600-R-97-130, *available at* http://www.epa. gov/emap/html/pubs/docs/groupdocs/landecol/atlas/atlas.html.

16. U.S. Envtl. Prot. Agency, Regional Vulnerability Assessment (ReVA) Program, http://www.epa.gov/reva (last visited Feb. 3, 2006).

"evaluate environmental conditions and known stressors within the Mid-Atlantic region" and "to identify those ecosystems most vulnerable to being lost or permanently harmed in the next 5 to 25 years and to determine which stressors are likely to cause the greatest risk."[17] The Mid-Atlantic Regional Assessment (MARA) is one of 19 EPA-supported studies focused on ecological indicators that relate to climate change.[18] MARA's environmental indicators focus especially on agriculture, forests, water, coasts, and human health.[19] Finally, the Atlantic Slope Consortium is one of five projects funded nationally by EPA's Estuarine and Great Lakes (EAGLES) Indicator Research Program under the Science to Achieve Results (STAR) Program.[20] This project is developing indicators that can produce "integrated assessments of the condition, health and sustainability of aquatic ecosystems" in order to improve decisionmaking affecting the region's watershed and estuarine resources.[21] The Atlantic Slope work is specifically intended to include attention to the users of the indicators and the human dimensions of indicators systems.[22]

EPA launched an agency-wide "environmental indicators initiative" in 2001 to "improve the Agency's ability to report on the status of and trends in environmental conditions and their impacts on human health and the nation's natural resources."[23] The initiative includes a long-term goal "to improve the indicators and

17. U.S. Envtl. Prot. Agency, What is ReVA?, http://www.epa.gov/reva/about.htm (last visited Feb. 3, 2006).

18. Mid-Atlantic Regional Assessment, http://www.essc.psu.edu/MARA (last visited Feb. 3, 2006).

19. Mid-Atlantic Regional Assessment, Key Topics, http://www.essc.psu.edu/MARA/topics/index.html (last visited Feb. 3, 2006).

20. The Consortium includes teams of researchers from Penn State University, the Smithsonian Environmental Research Center, the Virginia Institute of Marine Sciences, Eastern Carolina University, the Environmental Law Institute, and FTN Associates. Atlantic Slope Consortium, Overview, http://www.asc.psu.edu/overview.asp (last visited Feb. 3, 2006).

21. *Id.*

22. Atlantic Slope Consortium, Approach, http://www.asc.psu.edu/approach.asp (last visited Feb. 3, 2006).

23. U.S. Envtl. Prot. Agency, About the Environmental Indicators Initiative, http://www.epa.gov/ indicators/abouteii.htm (last visited Feb. 3, 2006). EPA describes environmental indicators as "scientific measurements that help measure over time the state of air, water, and land resources, pressures on those resources, and resulting effects on ecological condition and human health." U.S. ENVTL. PROT. AGENCY, DRAFT REPORT ON THE ENVIRONMENT 2003, at D-6 (2003), *available at* http://www.epa.gov/indicators/roe/html/roePDF.htm.

data that are used to guide the Agency's strategic plans, priorities, performance reports, and decisionmaking."[24] However, this project seems to be primarily directed at aggregating data for a national "state of the environment report" rather than on the development and maintenance of a suite of environmental indicators suitable for management decisions.[25] EPA's first draft report, released in 2003, covered five "theme" areas: human health, ecological conditions, clean air, pure water, and better land use.[26]

In addition to federally sponsored efforts to define and interpret environmental indicators, there are some significant privately-funded efforts. One of the most prominent is the Heinz Center's State of the Nation's Ecosystems Project.[27] This multi-year project is continuing to develop potential indicators at multiple scales for different ecological communities. EPA drew on the Heinz Center results for data used in the ecological indicators portions of the Technical Document accompanying the agency's 2003 Draft Report on the Environment.[28]

State governments and state environmental agencies have also defined environmental indicators for various management purposes. One of these indicator programs was an outgrowth of the movement toward "sustainable development" that arose after the 1992 Earth Summit in Rio de Janeiro. Minnesota's Environmental Indicator Initiative was a direct response to the state's multi-

24. U.S. Envtl. Prot. Agency, About the Environmental Indicators Initiative, http://www.epa.gov/ indicators/abouteii.htm (last visited Feb 3, 2006).

25. EPA's environmental indicators initiative appears to be an attempt to address the gap created by the discontinuation of the national "Environmental Quality" reports formerly issued by the Council on Environmental Quality under the National Environmental Policy Act. *See* 42 U.S.C. §§ 4341, 4344 (2005). In the late 1990s the CEQ ceased to issue these annual reports, based on its general counsel's interpretation of an omnibus appropriations bill provision eliminating the reports to Congress required under various laws. Arguably, this should not have ended CEQ's reporting obligation, as the primary duties of the CEQ under Title 2 of NEPA are to compile and analyze environmental data and to report each year "*to the President* on the state and condition of the environment" (emphasis supplied), a duty that was not abolished by removing the obligation of the President to report to Congress. 42 U.S.C. § 4344 (2), (7) (2005).

26. U.S. ENVTL. PROT. AGENCY, DRAFT REPORT ON THE ENVIRONMENT 2003 (2003), *available at* http://www.epa.gov/indicators/roe/html/roePDF.htm.

27. H. JOHN HEINZ III CTR. FOR SCI., ECON., AND THE ENV'T, THE STATE OF THE NATION'S ECOSYSTEMS: MEASURING THE LANDS, WATERS, AND LIVING RESOURCES OF THE UNITED STATES (2002), *available at* http://www.heinzctr.org/ecosystems/pdf_files/sotne_complete.pdf.

28. U.S. ENVTL. PROT. AGENCY, DRAFT REPORT ON THE ENVIRONMENT TECHNICAL DOCUMENT 5-1 to 5-77 (2003), EPA 600-R-03-050, *available at* http://www.epa.gov/indicators/ roe/html/roePDF.htm.

stakeholder Sustainable Development Initiative launched in 1993.[29] In other instances, state action has reflected a desire to use specific ecological indicators as a significant management input to its programs, as with Ohio's substantial reliance on aquatic biocriteria as the cornerstone of its water quality permitting program. Ohio uses a modified Index of Biotic Integrity (IBI) to establish baseline standards for all of its rivers and streams, using a system of reference waters. The biocriteria are then used to determine whether or not any particular water body meets its water quality standards.[30] Each of these efforts arose apart from any federal mandate or federal funding source.

B. Research on Environmental Indicator Design

During the past decade of environmental indicator development, the field has become more professionalized. Two academic journals are now devoted to environmental indicators: Environmental and Ecological Statistics, launched in 1994, and Ecological Indicators, launched in 2001.[31] In 2000, The National Research Council published a book defining the field and summarizing the case for environmental indicators.[32] The development of the field has also led to several attempts to identify criteria for sound environmental indicators.

In its work for EPA's state-oriented NEPPS program in 1995, Florida State University described eight *essential* criteria for an environmental indicator, and seven *preferable* criteria.[33] The researchers deemed it "essential" that an indicator: (1) be

29. ENVTL. INDICATORS INITIATIVE, DEVELOPING ENVIRONMENTAL INDICATORS FOR MINNESOTA: AN OVERVIEW 5 (1998), *available at* http://files.dnr.state.mn.us/eii/overview_a.pdf.

30. Chris O. Yoder & Edward T. Rankin, *Biological Criteria for Water Resources Management*, *in* MEASURES OF ENVIRONMENTAL PERFORMANCE AND ECOSYSTEM CONDITION 227-259 (Peter C. Schulze ed., 1999); Chris O. Yoder, *The Development and Use of Biological Criteria for Ohio Surface Waters*, *in* WATER QUALITY STANDARDS FOR THE 21ST CENTURY: PROCEEDINGS OF A NATIONAL CONFERENCE 139 (Gretchen H. Flock ed., 1989).

31. ENVIRONMENTAL AND ECOLOGICAL STATISTICS (Springer Sci. and Bus. Media, since 1994, online since 1997); ECOLOGICAL INDICATORS: INTEGRATING MONITORING, ASSESSMENT AND MANAGEMENT (Elsevier, since 2001).

32. COMM. TO EVALUATE INDICATORS FOR MONITORING AQUATIC AND TERRESTRIAL ENV'TS, NAT'L RESEARCH COUNCIL, ECOLOGICAL INDICATORS FOR THE NATION (2000), *available at* http://www.nap.edu/books/0309068452/html.

33. STATE ENVTL. GOALS AND INDICATORS PROJECT, FLA. CTR. FOR PUB. MGMT., PROSPECTIVE INDICATORS FOR STATE USE IN PERFORMANCE AGREEMENTS, OVERVIEW (1995), *available at* http://www.pepps.fsu.edu/segip/products/perform_agree/over.html.

measurable, (2) rely on sound data obtained through reproducible methods, (3) address an important environmental issue, (4) be relevant to a significant policy goal within that issue, (5) be highly correlated to the trends or conditions it is selected to represent, (6) be obtained at the appropriate geographic and temporal scale, (7) be tracked over time so that trends can be discerned, and (8) provide support for "making policy decisions." With respect to the last criterion, the researchers suggest that the indicator should not be so "highly specific or special" that it is useful only to technical staff rather than to "policy staff or management."[34] It is "preferable" that an indicator: (1) measure a "direct" impact on health or ecological conditions, (2) be sensitive to changes in conditions, (3) be simple and understandable to the public, (4) respond to cumulative stressors, (5) be comparable to prior measures, (6) be cost effective, and (7) provide early warning of environmental change.[35]

In 2000, EMAP researchers published detailed guidelines for evaluating the ecological indicators developed by EMAP's programs.[36] The guidelines identified four "phases" of indicator performance, concluding that an indicator should satisfy all four before it should be recommended for use. First, the indicator must demonstrate *conceptual relevance*, which means that the indicator must relate to some environmental management objective and provide information linked to the operation of some identified ecological function. Second, the indicator must demonstrate *feasibility of implementation*. This means that it can be tracked by standard, well-documented data collection methods and be supported both logistically and by appropriate information management systems. It must also be affordable and provide for quality assurance. Third, the indicator must demonstrate *response variability*, which means that measurement errors can be estimated and taken into account, that the indicator recognizes temporal variability within a single field season and across a period of years, and that it is sensitive to spatial variability and able to discriminate differences in conditions among separate sites along a known

34. *Id.*

35. *Id.*

36. U.S. ENVTL. PROT. AGENCY, EVALUATION GUIDELINES FOR ECOLOGICAL INDICATORS (Laura E. Jackson et al. eds., 2000), EPA 620-R-99-005, *available at* http://www.epa.gov/emap/html/pubs/docs/resdocs/ecol_ind.pdf.

gradient. Fourth, the indicator must support *interpretation and utility.* This means that it must meet data quality objectives so that a desired sensitivity and predictiveness can be achieved. The indicator must also define assessment thresholds (values that clearly delineate acceptable from unacceptable ecological conditions) and be linked to management actions.[37] With respect to this last area, "policy makers and resource managers must be able to recognize the implications of indicator results for stewardship, regulation, or research."[38]

Both the Florida State and EMAP analytic schemes focus primarily on indicator characteristics that address the scientific validity and sensitivity of the indicator as a *measure of change* in environmental conditions. But both also recognize that the indicator or indicator system must serve some *management objective.*[39] Important as these criteria are, however, most indicator programs have not attempted to identify expected users nor to understand the constraints that affect their ability to use indicators. Nor do indicator development and evaluation protocols typically specify what management decisions are to be driven (or at least directly affected) by well-designed, scientifically-valid indicators. Many recent experiments with environmental indicators have neglected to identify users and decisions at all. Without attention to such factors at an early stage, indicator systems rely on the bare hope that "if you build it, they will come."[40]

II. INSTITUTIONAL FACTORS AFFECTING INDICATOR UTILITY

We analyzed the performance of indicator systems in a number of states that have adopted environmental indicator systems for management purposes. We also examined institutional demands and constraints affecting decisionmakers in the Atlantic Slope Consortium study states.[41] We found that three significant

37. *Id.* at 1–5.

38. *Id.*

39. Other research has begun to address means of communicating indicator data effectively to members of the public and decisionmakers. *See, e.g.*, Andrew Schiller et al., *Communicating Ecological Indicators to Decisionmakers and the Public*, 5 CONSERVATION ECOLOGY (2001), http://www.consecol.org/vol5/iss1/art19/index.html.

40. FIELD OF DREAMS (Universal Studios 1989).

41. Delaware, Maryland, New Jersey, North Carolina, Pennsylvania, Virginia, and West Virginia. Atlantic Slope Consortium, Study Region, http://www.asc.psu.edu/updates.asp (last visited Feb. 3, 2006).

institutional issues potentially affect indicator usefulness.

First, the indicators must be relevant to an identified management purpose. Different indicators are needed for general assessments of environmental conditions than for priority setting, measuring program performance, writing rules, or conditioning permits. Many indicator programs do not identify these purposes in more than broad, vague terms; as a result, the indicators are often developed first and then go in search of a management purpose. In order to inform indicator selection and design, it is necessary to understand who the users are, what environmental or social "endpoints" are being sought by the managers who are expected to use the indicators, what capacities the users have to interpret technical information, and what legal and jurisdictional constraints apply to the decisions. The selected indicators must match the needs and capacities of the intended users.

Second, it is necessary to match indicator data to the relevant geographic scale of the decision that the decisionmakers are trying to address. For example, watershed-wide indicators may provide little guidance to a management entity attempting to make a decision affecting only a small land area within the watershed, or straddling two adjacent watersheds. Likewise, detailed information on the ecological condition of a particular tributary may provide only limited usable information to a manager attempting to deal with a different tributary in the same ecological region.

Third, it is necessary to determine which system can reliably supply valid indicator data to those who need it when they need it. This includes consideration of a number of issues including the mechanical requirements for data collection and maintenance, identification of the entity that interprets the data, what authority such an interpretation has, and how the information should flow from the data interpreters to the decisionmakers.

A. Identified Management Purpose

The *Evaluation Guidelines* developed by EMAP researchers in 2000 begin with the admonition that each environmental indicator must be "relevant" to a defined "management objective."[42] The intended use is the most important factor in determining which indicators to select and how to structure the system for collecting, interpreting,

42. U.S. ENVTL. PROT. AGENCY, *supra* note 36, at 1-1.

and delivering the indicators. Making the connection between indicator information and users is often neglected when indicator systems are established, which leads to disappointment when information that is perceived to be available does not lead to different decisions.[43]

The Atlantic Slope Consortium has identified five functional uses for environmental indicators that may help determine the potential users for any indicator or suite of indicators:[44]

(1) Condition Assessment: the indicator defines the condition of the affected environment/watershed.

(2) Stressor Diagnosis: the indicator defines sources of impairment and provides a basis for targeting preventive or remedial actions.

(3) Forecasting: the indicator shows the probable outcomes of alternative policy choices.

(4) Management Evaluation: the indicator determines whether the public policy actions performed as expected.

(5) Communication: the indicator informs the public, legislators, and others concerned about the area.

The ability to use indicators for any of these purposes depends upon the characteristics of the user, including constraints, and upon the relationship of the indicator to an identifiable management objective within the power of the user.

1. Decisionmaker Characteristics and Objectives

In order to determine the opportunities and constraints affecting the use of environmental indicators in decisionmaking, we examined the potential users in detail. The Atlantic Slope Consortium researchers developed environmental indicators and tested them in 14-digit hydrologic unit classification (HUC)

43. Michael Patton has observed that evaluation systems (of which environmental indicators are a type) often "fall prey to the seemingly stakeholder-oriented 'identification of audience' approach" when it comes to identifying users. He observes that putative users "usually turn out to be relatively passive groups of largely anonymous faces: the feds, state officials, the legislature, funders, clients, the program staff, the public, and so forth." MICHAEL QUINN PATTON, UTILIZATION-FOCUSED EVALUATION 54 (3d ed. 1997). Patton notes that another typical temptation is "to put off attending to and planning for use from the beginning." *Id.* at 57.

44. Denice Heller Wardrop et al., Developing and Communicating a Taxonomy of Ecological Indicators: A Case Study from the Mid-Atlantic (unpublished manuscript, submitted to EcoHealth Dec. 2004).

watersheds and small estuarine segments.[45] We identified the public decisionmakers in each watershed and examined: (1) their institutional characteristics, and (2) their decisional objectives and applicable constraints.

Institutional characteristics include the kind of body that is charged with making a decision, its technical capacity to understand and use indicators, and the kinds of decisions it makes—whether they be one-time, sporadic, or continuous. Decisional objectives and constraints are usually defined by laws that specify what decisions are to be made, and that often define what facts may be considered in making a decision. Laws may provide that a fact (as expressed in an environmental indicator) *must* be considered by the decisionmaker, that it *may* be considered but is not determinative, or that it *may not* be considered. For example, if a legal provision requires a state department of the environment to use chemical concentration limits to determine whether water quality is impaired, information on biotic integrity may not be legally relevant even though it would undeniably be useful in evaluating a broader social goal of clean water. Likewise, if loss of forest cover in a municipality will lead to the regional decline of songbirds, the municipality will be able to take this factor into account in evaluating a proposed housing development only if it has included related forest cover or wildlife environmental factors in its subdivision or site plan approval ordinances.

The following potential users for environmental indicators were found in the study watersheds and small estuary segments. They include local governments with jurisdiction over private land use decisions, planning agencies, environmental regulators, conservation districts, agencies responsible for infrastructure, fish and wildlife agencies, economic development agencies, and legislatures. Each of these public decisionmakers has a distinct set of capacities to use and apply environmental indicators, and each has authority to make different types of decisions, which are more, or less, susceptible to alteration based on the availability of scientific information on conditions, diagnosis, forecasting, or management. The identification of these capacities and decisional objectives is based upon our review of entities in the study watersheds and states.

45. Atlantic Slope Consortium, *supra* note 22.

Local Land Use Regulatory Boards. Locally elected and appointed boards, such as planning boards and boards of supervisors or town councils, are the primary decisionmakers responsible for adopting land use plans and zoning ordinances, and for granting or denying development approvals. In some states the local unit of municipal government, be it town, borough, city, or township, exercises plenary authority over planning, zoning, and subdivision of land.[46] In others, county governments exercise this land use authority except where there is an incorporated city exercising such powers, or in systems such as Virginia where counties and cities are autonomous entities.[47]

The Atlantic Slope Consortium found that the number of local government entities with land use planning and zoning authority within each study watershed ranged anywhere from 1 to 9. The median study watershed included three jurisdictions with land use authority (typically a county and two incorporated towns or cities). The number of such jurisdictions was higher in Pennsylvania and New Jersey, where planning and zoning is located at the municipal level of government. Thus, if indicators suggest the need for consistent land use decisions affecting an entire small watershed, numerous autonomous jurisdictions must be approached. The technical capacity of local land use decisionmaking bodies varies substantially; hence their ability to use environmental indicators. Many jurisdictions, including most counties, have professional planners to assist their appointed planning boards and elected officials. But many others, especially where the local township government regulates land uses, do not have professional staff but rely on private engineers and consultants who are retained for major planning revisions but are not engaged in day-to-day review of development applications.

Local land use regulators have many different decision objectives, some of which relate to environmental conditions while others do not. However, their authority as defined by state law typically extends to protection of the "public health, safety, morals, and general welfare."[48] In almost every case this means that at least

46. 53 PA. STAT. ANN. §§ 10209.1, 10301 (West 1988); N.J. STAT. ANN. §§ 40:55D-25, -28 (West 2005).

47. DEL. CODE ANN. tit. 9, §§ 2651–2662, §§ 4951–4962, §§ 6951–6962. (1998); DEL. CODE ANN. tit. 22 § 301 (2005); MD. ANN. CODE, art. 66B §§ 3.01, 4.01 (2005); N.C. GEN. STAT. ANN. §§ 153A-320, 160A-360 (West 2005); VA. CODE ANN. §§ 15.2-2280, -2281 (West 2005).

48. *See* Model Code § 7-201, Growing Smart Legislative Guidebook 7–68 (Stuart Meck ed.,

when preparing a comprehensive plan, jurisdictions are authorized (but not always required) to assess the condition of environmental resources,[49] thus providing a basis for examining environmental indicators if any are available. Some states require local comprehensive plans to include a planning element identifying and prescribing land use objectives for "sensitive areas."[50] Given the amount of discretion exercised by local government boards, environmental indicators can be of great value in preparing comprehensive plans and zoning ordinances, or in approving large scale planned unit developments. However, the demand for such information by particular jurisdictions is likely to be one-time or sporadic unless there is a continuing obligation to update comprehensive plans and ordinances, which is not the case in most of the jurisdictions studied,[51] or unless the comprehensive plan itself calls for the continuing collection and maintenance of such information.[52]

In contrast with their planning function, land use planning boards and governing boards typically exercise minimal discretion when they apply existing rules to applications for subdivisions or to developments that are authorized "by right" under existing zoning. This means that indicators are likely to be regarded as having minimal value or relevance in addressing subdivisions of land where the comprehensive plan and zoning regulations have not already clearly defined environmental objectives.[53]

Regional Planning Entities. Councils of Governments, Planning District Commissions, Metropolitan Planning Organizations, and similar bodies are multi-municipal and often multi-county

2002).

49. Linda Breggin & Susan George, *Planning for Biodiversity: Sources of Authority in State Land Use Laws*, 22 VA. ENVTL. L.J. 81, 92–94 (2003).

50. *E.g.*, MD. ANN. CODE art. 66B, § 3.05(a)(4)(viii) (2005) (sensitive areas element).

51. Only three of the states in the Atlantic Slope study area require regular updates of comprehensive plans. New Jersey requires municipalities to update their comprehensive plans every six years. N.J. STAT. ANN. §§40:55D-89 to -89.1 (West 2005). Pennsylvania law requires municipalities to "review" comprehensive plans "at least every ten years," PA. STAT. ANN. tit. 53, § 10301(c) (West 2005), but failure to do so has no legal consequence. Maryland requires plans to be updated and revised every six years. MD. ANN. CODE art. 66B, §§ 3.01(b), 1.03(b), (d) (2005).

52. Such requirements can be written into the plan. *See, e.g.*, COUNTY OF ALBEMARLE, VA., COMPREHENSIVE PLAN: NATURAL RESOURCES AND CULTURAL ASSETS 84 (1999), *available at* http://www.albemarle.org/department.asp?department=planning&relpage=3003 (updating biological resources information).

53. JAMES M. MCELFISH, JR., NATURE-FRIENDLY ORDINANCES 69–81 (2004).

organizations that supply planning expertise, data, and technical capacity to local governments.[54] Regional entities usually have minimal authority, or no authority, over land use decisions of the local governments, but provide advice and identify issues of regional concern.[55] They are generally governed by representatives of the participating local governments served by the regional body, and have professional staff including planners, demographers, and engineers.

The primary role of these organizations is to serve as a forum for consideration of regional needs and priorities, and as a provider of data and technical expertise for use by others, such as their constituent local or county governments, who make decisions. They typically consider issues of regional economic development, project regional demographic and social trends, assist local planning processes, and sometimes address regional housing needs. Regional organizations also serve a specialized role under the federal TEA-21 transportation planning program.[56] Metropolitan Planning Organizations evaluate regional planning and transportation needs, designate proposed projects for potential federal funding under the required regional Transportation Improvement Plans for metropolitan areas, and provide input to the overall State Transportation Plan that governs state allocations of federal transportation dollars.[57] However, they do not control approval of transportation projects or transportation budgets.[58]

Regional planning entities have the technical capacity to use and interpret environmental indicators, maintain data and series of data over time, and transmit indicator results to their constituent local governments and others in the region. Because their geographical coverage is fairly large and their institutional capacities emphasize compiling and disseminating information for decisions by others, they may be particularly useful institutions in a system intended to convey environmental indicators to diffuse decisionmakers.

Specialized Land or Water Area Agencies. State coastal zone

54. Nationally such bodies are served by an association, the Association of Metropolitan Planning Organizations (AMPO), http://www.ampo.org (last visited Feb. 3, 2006).

55. Such regional planning service organizations include Virginia's Multi-County Planning District Commissions. VA. CODE ANN. § 15.2-4207 (West 2005).

56. 23 U.S.C. § 134 (2000), 23 CFR §§ 450.300–.336 (2005).

57. 23 U.S.C. §§ 134, 135 (2000).

58. 23 U.S.C. § 135 (2000).

oversight agencies,[59] critical areas commissions,[60] and state and multi-state river basin commissions (e.g. Susquehanna, Delaware),[61] are entities that exercise a narrow set of decisionmaking functions defined by state or federal law or compact. These entities are staffed by technically trained professionals and have the capacity to use, compile, and maintain environmental indicator data. They engage in some standard setting and provision of technical assistance; for example, critical areas oversight bodies reviewing proposed local government decisions. They also conduct regulatory review of particular decisions, *e.g.* reviewing the consistency of a proposed activity with a coastal zone management plan, or proposed water withdrawal from a river basin.

These bodies may be able to serve as focal points for the collection, maintenance, and dissemination of indicator data and findings to other users. They are themselves potential users of environmental indicators as they carry out their decisionmaking functions relating to specific resources. However, most of their decisions are not discretionary, but are limited to approval or disapproval of particular activities according to articulated rules. For example, a critical areas agency might need to determine whether a proposed dock is really an authorized accessory use in a waterfront critical area, but not whether such a structure is good or bad for oysters.

Environmental Regulatory Agencies. State environment departments (Departments of Environmental Protection or Environmental

59. *E.g.*, Delaware's Division of Soil and Water Conservation, within its Department of Natural Resources and Environmental Control is the lead agency for Delaware's Coastal Zone Act and must examine and grant or deny permit approval for industrial and other uses within Delaware's designated coastal zone. DEL. CODE ANN. tit. 7, §§ 7001–7013 (2005). State coastal zone management agencies make the land management review and "consistency" determinations called for under the federal Coastal Zone Management Act. 16 U.S.C. § 1455(d) (2000).

60. *E.g.*, Maryland's Chesapeake Bay Critical Areas Commission, which is charged with developing criteria for local government resource protection programs and designation of critical areas, as well as oversight of decisions in the critical area. MD. CODE ANN., [NAT. RES.] §§ 8-1803, -1806 (2005). Compare the role of Virginia's Chesapeake Bay Local Assistance Board (recently merged into the Department of Conservation and Natural Resources) under VA. CODE ANN. § 10.1-2100 (2005) (criteria for preservation areas and review of local actions).

61. SUSQUEHANNA RIVER BASIN COMM'N, SUSQUEHANNA RIVER BASIN COMPACT (May 1972), *available at* http://www.srbc.net/docs/srbc_compact.pdf; DEL. RIVER BASIN COMM'N, DELAWARE RIVER BASIN COMPACT (Oct. 27, 1961), *available at* http://www.state.nj.us/drbc/regs/compa.pdf.

Quality), the U.S. Environmental Protection Agency (EPA), and the U.S. Army Corps of Engineers (for wetlands regulation), have decisionmaking authority over numerous proposed activities affecting lands and waters. They set regulatory standards, implement programs, monitor environmental conditions, and conduct inspections and enforcement of facilities. These agencies maintain substantial technical staff, database capability, and varying levels of research capacity. They are frequently generators of environmental data used in developing and powering systems of environmental indicators, and they have the technical capacity to use and maintain indicator systems, at least at the Department-wide level.

Environmental regulators generally have discretion in setting standards and determining their monitoring, inspection, and enforcement agendas, subject to budgetary and political constraints. These agencies are not empowered to exercise discretion for the general welfare, but must limit their decisions to standards prescribed by law and regulation to protect public health and environmental quality. For example, under the Clean Water Act, the U.S. EPA and state agencies have the duty to restore and maintain the "chemical, physical, and biological integrity" of the nation's waters.[62] However, they must do so not by approving or disapproving any proposed uses that might improve or impair this integrity as demonstrated or predicted by a set of reliable environmental indicators, but by making a set of decisions prescribed and circumscribed by law.[63] Within these constraints, however, environmental regulatory agencies can be repeat users of environmental indicators data for assessment, diagnosis of stressors, targeting, forecasting, communication, and evaluation of program performance.

For example, consider water quality management and decisionmaking. State environmental agencies must identify designated uses for state waters and set water quality standards to protect those uses.[64] Environmental indicators can be used to inform these water quality decisions by indicating current status,

62. 33 U.S.C. § 1251(a) (2000).

63. Their broadest discretion in this context is to review applications for federal permits and licenses to determine, by whatever means, whether any resulting discharge will violate state water quality standards. 33 U.S.C. § 1341 (2000) (so-called "section 401 water quality certification").

64. 33 U.S.C. § 1313 (2000).

sources of impairment, and/or conditions for restoration. Decisions about whether to issue permits for pollutant discharges to these waters then must be made by taking into account both the technology standards established by EPA and the water quality-based limitations needed to meet the uses designated by the states.[65] Environmental indicators are less useful in making these types of individualized decisions, unless the use designations and state water quality standards are written in such a way as to facilitate use of such data in permitting decisions. For example, water quality standards that define ecological health rather than simply chemical concentrations as measures of impairment specifically contemplate inquiry into whether certain classes of organisms are thriving, declining, or absent. In contrast, standards that reference chemical concentrations provide little basis for a permitting agency's use of an assessment showing the status of benthic organisms. Nevertheless, even with such constraints, indicators may be useful in making management decisions about scheduling for permitting, development of additional permit conditions, and communicating with the public.

States are required by law to inventory their "impaired waters" and to prepare plans for restoring their health.[66] Plans for impaired waters, called Total Maximum Daily Loads (TMDLs), provide another opportunity for environmental indicators to inform and influence decisionmaking, particularly because TMDLs must address nonpoint sources of water pollution from unregulated runoff and land uses as well as regulated point source discharges.[67] Environmental indicators can help agencies determine which unregulated land uses are most significant and where the greatest improvements can be made. State environmental agencies could benefit greatly from environmental indicators in evaluating sources, trends, solutions, management, and communications in establishing a TMDL. Moreover, because the TMDL process is a technical decision, the capacity to apply indicator information exists at the point of decision.[68]

65. 33 U.S.C. §§ 1311, 1312 (2000).

66. 33 U.S.C. § 1313(d) (2000).

67. For a detailed critical review of the TMDL decision process see OLIVER A. HOUCK, THE CLEAN AIR ACT TMDL PROGRAM: LAW, POLICY, AND IMPLEMENTATION (2d ed. 2002).

68. It should be noted, however, that while indicators may inform the development of a TMDL, they may not be able to drive the decision on implementation. Control of water quality, particularly in the nonpoint sector, is in the hands of many different actors

In many areas, state and federal environmental regulatory agencies present the best case for use of environmental indicators. Not only are indicators relevant to the decisions within their purview, but the agencies have both the technical capability to understand and use the information and ongoing responsibilities that justify their repeated use of such information. The Atlantic Slope Consortium's socioeconomic research team found, through a survey instrument, that state and federal environmental officials engaged in water quality management expressed a very high degree of support for indicators to assist their decisionmaking. Ninety-one percent of the state water quality officials used indicators in setting priorities, and 85 percent used indicators for monitoring and assessment of conditions. Seventy-five percent of the federal water quality officials reported their use of indicators for both purposes, and both the state and federal officials assigned an importance rank of 4.5 (on a scale of 1–5) for the use of indicators in monitoring and assessment functions. The same officials gave lower values (4.0 and 3.7, respectively) for the use of indicators in setting priorities.[69]

Soil and Water Conservation Districts. Conservation districts are county level, federally recognized districts operating under state laws with volunteer boards of landowners and small professional staffs.[70] They focus on delivery of technical assistance, federal agricultural and conservation services, and dollars to owners of farm and forest lands. Working in collaboration with U.S. Dept. of Agriculture agencies and state agriculture and natural resource agencies, these districts respond to landowner applications and requests, while promoting the availability of federal cost share and technical assistance programs including the Conservation Reserve Program, Conservation Reserve Enhancement Program, Environmental Quality Incentives Program, Forest Land Enhancement Program, and others administered by the USDA Natural Resources Conservation Service, Farm Services Agency, and

(including other decisionmakers listed in this article), and they have varying abilities to use the data in making the decisions that actually control land use choices.

69. Amy Balog, User Perspectives on Environmental Indicators for Aquatic Ecosystems: Results from Interviews with Water Quality Officials in the Mid-Atlantic States (2003) (unpublished master's thesis, Penn State University) (on file with authors).

70. NAT'L ASS'N OF CONSERVATION DISTS., ABOUT CONSERVATION DISTRICTS, http://www.nacdnet.org/about/aboutcds.htm (last visited Feb. 3, 2006).

others.[71] Conservation districts are potential users of environmental indicators in targeting programs and outreach activities that allow for targeting or that encourage watershed-based coordination.

Because conservation districts have repeated functions affecting the same lands and landowners, the availability of a time series of indicators could be quite useful to them if delivered in a usable form; for example, defining desirable riparian buffer widths for a watershed or assisting with the targeting of outreach efforts to landowners whose lands have the greatest potential impact on habitat, water quality, or other resource objectives. At the same time, however, districts are constrained by their need to focus on delivery of cost-share and technical assistance to eligible applicants, and they may not be able to use environmental indicators in many of their day-to-day activities, which include responding to landowner "clients" seeking access to programs they administer under federal and state laws.

Water and Sewer Infrastructure Agencies. The provision of water and sewer support for development and developed uses is the responsibility of public authorities, municipal entities, or private companies subject to state utility regulation. Their decisions are constrained by state water law, federal and state environmental standards, and state and local financing and debt requirements including state infrastructure finance institutions.[72] The responsible entities typically have an engineering staff and may have an environmental compliance staff. Decisions are chiefly aimed at providing service to identified populations, but the prescribed issues are typically those of timing, engineering, cost, and service areas. Because these entities have a repeated need for data, forecasting, and evaluation of past choices, indicators can be valuable to their decisions and may influence location, timing, and mitigation. State financing agencies may also be able to use indicator information in evaluating how to allocate scarce resources from the federally-supported State Revolving Funds under the Clean Water and Safe Drinking Water Acts.[73]

Transportation Infrastructure Agencies. State Departments of

71. For summaries of conservation provisions of 1996 and 2002 Farm Bills, see ECONOMIC RESEARCH SERV., U.S. DEP'T OF AGRIC., FARM POLICY TITLE II CONSERVATION (2002), *available at* http://www.ers.usda.gov/Features/FarmBill/Titles/TitleIIConservation.htm#retirement.

72. NAT'L RESEARCH COUNCIL, REGIONAL COOPERATION FOR WATER QUALITY IMPROVEMENT IN SOUTHWESTERN PENNSYLVANIA 214–216 (2005).

73. 33 U.S.C. §§ 1381–1387 (2000); 42 U.S.C. § 300j-12 (2000).

Transportation, the Federal Department of Transportation, and county and local governments plan and fund transportation improvements. Metropolitan Planning Organizations, discussed above, also play a role in making decisions about where to locate transportation infrastructure and which projects to prioritize.[74] The transportation agencies are typically subject to political influence but also have a substantial technical and engineering professional staff, including environmental engineers with expertise in mitigation. Decisions involve a great deal of discretion, subject to federal and state environmental laws dealing with wetlands, air pollution, stream crossing, and endangered species. The agencies have repeated need for environmental data for use in forecasting, design and selection of routes, and designing mitigation measures. Indicators can be very valuable to these agencies but may only rarely be determinative of their decisions. The agencies typically plan routes based on demand, and then mitigate environmental impacts based on available data.[75] Only rarely do environmental indicators determine whether roads or other transportation infrastructure are sited in the first place.[76]

Fish and Wildlife Management Agencies. State fish and wildlife agencies are typically headed or overseen by politically appointed officials or boards and maintain professional staff conversant with biological sciences and land management. These agencies typically have very substantial discretion to set limits and seasons and may act to protect habitat or populations of fish and wildlife,[77] at times engaging in habitat enhancement or restoration. They also serve as trustees for natural resource damages under federal law[78] and hence need information on both losses and rehabilitation strategies. However, fish and wildlife management agencies typically have very limited jurisdiction, if any, over activities on privately owned land that are not directly related to setting the terms and conditions for the taking of wildlife.

Fish and wildlife agencies can be repeat users of environmental indicators data for assessment, diagnosis of stressors, targeting,

74. 23 U.S.C. § 134 (2000).

75. PATRICIA WHITE & MICHELLE ERNST, SECOND NATURE: IMPROVING TRANSPORTATION WITHOUT PUTTING NATURE SECOND 14 (2005).

76. *Id. at 61.*

77. *E.g.*, 34 PA. CONS. STAT. ANN. §§ 2101–2102 (West 2005) (authority of Pennsylvania Game Commission over game or wildlife species).

78. 42 U.S.C. § 9607(f) (2000); 33 U.S.C. § 2706 (2000).

forecasting, communication, and evaluation of program performance. Because of their technical competence, they are also likely users of such information in decisionmaking. Regional fisheries councils established under the Magnuson-Stevens Act may also be users of environmental indicators for management decisions affecting the marine waters off multiple states.[79]

Purchasers and Managers of Conservation Lands. The purchasers and managers of land and easements include state conservation and agricultural agencies, local governments, nonprofit land trusts, and federal agencies.[80] They often have substantial technical capacity and engage in priority setting, land management, and conservation restoration activities. Conservation land holders typically have substantial discretion in targeting particular areas for purchase over others, but may be constrained by a specific mission, such as forest land conservation, productive agricultural land conservation, or recreational land conservation. As managers of lands they already own, these entities also generally have fairly broad discretion in preparing management plans.[81] Conservation land holders and managers can be repeat users of environmental indicators data for assessment, diagnosis of stressors, targeting, forecasting, communication, and evaluation of program performance. Some acquisitions programs have developed detailed and well-articulated priorities schemes that can be served by indicators data.[82] In general these entities have the capacity to use environmental indicators.

Economic Development Agencies. These state and local agencies may administer grant and loan programs, operate technical assistance programs, or engage actively in development and redevelopment deals. Economic development agencies frequently have no environmental mission or expertise, and environmental issues are often deferred until the permitting of a particular project under state and federal environmental regulations. State economic

79. 16 U.S.C. § 1852 (2000).

80. State land acquisition programs are identified in ENVTL. LAW INST., SMART LINKS: TURNING CONSERVATION DOLLARS INTO SMART GROWTH OPPORTUNITIES 5–23 (2002), *available at* http://www.eli.org/pdf/d12.04.pdf.

81. For example, Pennsylvania manages the over 2.1 million acres of its state forest land system under a third party certification of sustainability conferred by the internationally recognized Forest Stewardship Council. PA. BUREAU OF FORESTRY, STATE FOREST RESOURCE MANAGEMENT PLAN, http://www.dcnr.state.pa.us/forestry/sfrmp/index.htm (last visited Feb. 3, 2006).

82. DEL. CODE ANN. tit. 7, §§ 7501–7510 (2005).

development agencies typically have discretion subject to fairly substantial political control. The factors they must consider are typically limited to jobs and economic factors rather than broad discretion to include environmental concerns.[83] However, they may be able to consider some elements to which environmental indicators are relevant—such as the availability of an adequate long-term water supply, or the recreational or tourism potential of a particular waterway or parcel of land. These entities could be repeat users of indicators data, but may also determine that such information is outside their legal jurisdiction and hence neither relevant nor permissible as a basis for decisionmaking absent statutory authorization.

Legislators. These elected, usually part-time, state officials and their professional staffs make decisions on new programs, state priorities, budgeting and funding, and whether to retain or delegate substantial control over the implementation of particular programs. Legislatures also set the rules under which local units of government make their decisions.[84] They have substantial discretion over many areas of their work, and, in making decisions that involve local environments, could benefit from environmental indicators. However, they also have broad and competing areas of interest and focus that make continuing recourse to a defined set of environmental indicators far less certain.

Legislatures have a sporadic, yet ongoing, interest in environmental conditions, including assessment, stressors, targeting, forecasting, communication, and evaluation of program performance. Legislators have broad discretion to consider indicators but are not required to use environmental indicators or to consider environmental impacts when making decisions.[85] As

83. *E.g.*, ENVTL. LAW INST., VIRGINIA'S ECONOMIC INCENTIVES: MISSED OPPORTUNITIES FOR SUSTAINABLE GROWTH 23–24 (2001), *available at* http://www.eli.org/pdf/VASMARTGROWTH.PDF.

84. Local governments are creatures of the state government, and they exercise the powers conferred or withheld by state government. The scope of local autonomy conferred by state legislatures ranges from "home rule" localities in some states to strict enforcement of "Dillon's Rule" in states (such as Virginia) that jealously guard the state's power vis-a-vis its municipalities. *See generally* RUTHERFORD PLATT, LAND USE & SOCIETY: GEOGRAPHY, LAW AND PUBLIC POLICY 142–145 (1996).

85. Although several state constitutions, including Pennsylvania's and Virginia's, specify a constitutional right to a clean environment or a state policy of environmental protection, the courts have not extended the obligation to legislative acts. PA. CONST. art. I, § 27; VA. CONST. art. XI, § 1.

they are often not good repositories of indicator data, legislatures turn to organizations and agencies that have a continuing role when they need data or seek to answer a particular question. Legislatures in some parts of the U.S. have created environmental indicator tracking systems as a general measure of environmental status.[86] Some legislatures have created and funded independent sources of environmental indicator data, such as the Virginia Institute of Marine Science, that can inform decisions on an ongoing, on-call basis.[87]

2. Connecting System Design with Management Objectives

Most environmental indicators systems have been built without clear attention to the management objectives they are intended to serve. Several states in the Mid-Atlantic region have attempted to construct suites of environmental indicators for management purposes. Their experiences show the significance of identifying connections between indicators and management decisions. Pennsylvania, for its part, designed a system of environmental indicators and then attempted to generate local management purposes these could inform. In contrast, New Jersey built a scientifically rigorous system while simultaneously constructing a complex management system. Maryland, within the context of the Chesapeake Bay program, began with objectives and designed a system of indicators designed to measure progress towards those objectives.

In 2001, the Pennsylvania Department of Environmental Protection (PADEP) launched the "Environmental Futures Planning Process" (EFP2), which was an effort to coordinate Department activities and measure progress according to 17 environmental indicators. These were grouped around three goals: conserving and restoring natural resources, reducing harmful effects from environmental contaminants and conditions, and engaging citizens as stewards of the environment.[88] The data to drive the indicators were mostly collected from existing reports of

86. *E.g.*, Minnesota Milestones is a "sustainable development" indicators program established in 1991. MINN. DEP'T ADMIN., MINNESOTA MILESTONES: MEASURES THAT MATTER, http://server. admin.state.mn.us/mm (last visited Feb. 3, 2006).

87. The Coll. of William and Mary, Virginia Institute of Marine Science, http://www.vims.edu (last visited Feb. 3, 2006).

88. PENN DEP'T OF ENVTL. PROT., ENVIRONMENTAL FUTURES PLANNING PROCESS (June. 24, 2002), http://www.dep.state.pa.us/hosting/efp2.

state environmental agencies. The PADEP delegated responsibility for using the indicators to PADEP-organized groups in 34 watersheds, covering the entire state.[89] The indicators were to be used to identify objectives and guide management actions, which would be identified on a landscape basis by watershed, even though not all of the indicators were watershed-focused. Many dealt with species diversity, days and population affected by adverse air quality, and other issues. PADEP directed its regional staff and other stakeholders who could be mobilized by the watershed teams to identify planning objectives and develop action plans using the indicators.[90]

The result was the identification by the watershed teams in 2002 of over 3100 objectives and submission of over 450 proposed action plans covering wide ranges of topics and options. Some of the action plans were quite detailed, while others were less so. Some called for actions within the control of PADEP units, while others called for actions outside the agency's jurisdiction or for actions that would require new legislation. This proved to be such an overwhelming and diverse response that the coordinators of EFP2 organized teams to evaluate the responses in 2003. They subsequently paused the entire process in order to consider how to deal with management of the program. Development of the EFP2 indicator scheme before defining clear management objectives, and the rapid devolution of the implementation process, impeded the utility of the program.[91]

The New Jersey Department of Environmental Protection (NJDEP) initiated a results-based environmental management system that set goals and established indicators to monitor the state's progress towards those goals. The National Environmental Performance Partnership System (NEPPS) was the primary impetus behind NJDEP's commitment to the development of a result-based management system based on a comprehensive set of environmental indicators.[92] In the 1990s, under the Whitman

89. PENN DEP'T OF ENVTL. PROT., ENVIRONMENTAL FUTURES PLANNING PROCESS, Watershed Planning Teams (Aug. 6, 2002), http://www.dep.state.pa.us/hosting/efp2/contact/34leaders.htm.

90. PENN DEPT. OF ENVTL. PROT., *supra* note 88.

91. Interviews by James M. McElfish, Jr. with Pennsylvania Department of Environmental Protection staff (Dec. 2003 and May 2004).

92. *See e.g.*, N.J. DEP'T OF ENVTL. PROT., STRATEGIC PLAN: 1998–2001, 4 (1998), *available at* http://www.scc.rutgers.edu/cei/about/PDF%20Files/SP%2098_01.pdf (mentioning how

administration, New Jersey was moving to implement a results-based management system that would in part be based on a hierarchical planning structure.[93] At the top of the hierarchy was the New Jersey Sustainable State Initiative, and NJDEP's mission statement and Strategic Plan were tied to the goals of that broader Initiative.[94] NJDEP's Performance Partnership Agreement (PPA) with EPA acted as the Department's more comprehensive planning document and included indicator information and strategies, while the NJDEP's Strategic Plan operationalized the Sustainable State Initiative.[95] Each NJDEP program was responsible for submitting an annual work plan that described its progress towards meeting the applicable goals. In 2000, NJDEP coordinated the release of the interagency Sustainable State Report, *Living with the Future in Mind*, in an effort to increase the link between the NEPPS process and the Sustainable State Initiative.[96]

The NJDEP NEPPS process was coordinated by a Department-wide Steering Committee, which also oversaw the state's environmental indicators system.[97] The NEPPS Steering Committee consisted of about 35 individuals representing all the NJDEP program areas and included several representatives from U.S. EPA Region II.[98] The Committee supervised development of the PPA, Annual Performance Reports, and New Jersey State of the Environment Reports, and assisted the NJDEP management team with annual Environmental Progress Briefings. The NEPPS Steering Committee also made recommendations for the

the Strategic Plan was built upon the process established by the NEPPS program).

93. N.J. DEP'T OF ENVTL. PROT. & U.S. ENVTL. PROT. AGENCY, NEW JERSEY ENVIRONMENTAL PERFORMANCE PARTNERSHIP AGREEMENT: FISCAL YEARS 2002-2004, 8–10 (2001), *available at* http://njedl.rutgers.edu/ftp/PDFs/2136.pdf.

94. Marjorie B. Kaplan & Leslie J. McGeorge, *The Utility of Environmental Indicators for Policymaking and Evaluation From a State Perspective: The New Jersey Experience*, Invited guest Editorial: RISK POLICY REPORT para. 7–8, http://www.scc.rutgers.edu/cei/Resources/may4sg.doc (last visited Feb. 3, 2006). The Sustainable State Initiative was launched in 1995 to identify long term trends that would enhance or degrade New Jersey's quality of life. It identified 41 indicators. NEW JERSEY FUTURE, LIVING WITH THE FUTURE IN MIND 7 (2000).

95. N.J. DEP'T OF ENVTL. PROT. & U.S. ENVTL. PROT. AGENCY, *supra* note 93, at 1. The PPA was also aligned with the State Development and Redevelopment Plan as well as with EPA's Region II and national strategic plans. *Id.* at 8–10.

96. *Id.* at 1.

97. *Id.* at 6. U.S. EPA Region II also has its own NEPPS Steering Committee that oversees the development of NEPPS programs and policies (including the use of environmental indicators) in the region. *See id.* at 7–8.

98. *Id.* at unnumbered pages following cover.

integration of indicators into specific department activities, including budgetary priorities.[99]

NJDEP has approximately 130 environmental indicators expressed in its PPA and the Environmental Indicators Technical Report.[100] The indicators included in the PPA are those for which the department had reliable data.[101] Most of the indicators in the NJ EI Technical Report were developed in accordance with the NEPPS program, but a few—solid waste, land and natural resources, and climate change indicators—were exclusively within NJDEP's domain and not required by NEPPS. The indicators were linked to departmental goals.[102] Problems that NJDEP faced in implementing its indicator program included: data quality, availability, representativeness, the need to "better align goals and measures," incorporating new standards or criteria into the indicator and trend data, emphasizing progress as opposed to "bean" counting, integrating indicators into mandatory reporting mechanisms, establishing better links between cause and condition indicators, and "nesting indicators at different scales."[103]

Maryland published two sets of indicators in 1999, based on a NEPPS agreement with EPA, as part of a strategic planning effort.[104] Later it adopted the Maryland Integrated Watershed and Data Information System, which maps environmental indicator data at the 8-digit HUC watershed scale for the entire state.[105] Maryland also integrates its water quality, forestry, and certain other programs with an overarching management system that uses agreed

99. *Id.* at 6–7.

100. *Id.* at 10–11. (Count by authors). The Technical Report documents the information that supports the environmental indicators. *Id.* at 29.

101. *Id.* at 16.

102. Kaplan & McGeorge, *supra* note 95, at para. 7–8.

103. Kaplan & McGeorge, *supra* note 95, at para. 11. The scale problem is that indicators are often available over a larger or smaller geographical area than the area where the decision must be made. The difficulty is in determining how to interpret the information that is available when making the decisions, and how (or whether) to interpolate between different scales, particularly when the information may have been collected for different purposes or with different protocols appropriate to the original scale of the indicator but not necessarily to the decision at hand.

104. MD. DEP'T OF THE ENV'T, ENVIRONMENTAL INDICATORS, http://www.mde.state.md.us/AboutMDE/Reports/indicators.asp (last visited Feb. 3, 2006).

105. MD. DEP'T OF NATURAL RES., WATERSHED INDICATORS, http://www.dnr.state.md.us/watersheds/surf/indic/md/md_indic.html (last visited Feb. 3, 2006). The Hydrologic Unit Code (HUC) system is explained at http://water.usgs.gov/GIS/huc.html (last visited Feb. 3, 2006). There are just 2150 8-digit HUC watersheds nationally, so these hydrologic units typically include parts of multiple counties.

upon metrics to measure progress toward improving the health of the Chesapeake Bay.[106]

The multi-state Chesapeake Bay Program was established with the signing of the first Chesapeake Bay Agreement, a commitment by Maryland, Pennsylvania, Virginia, the District of Columbia, the EPA, and the Chesapeake Bay Commission in 1983.[107] In 1987, the parties signed a new agreement that set specific goals. The parties pledged to reduce phosphorus and nitrogen loads in the Bay by 40 percent from 1985 levels by 2000,[108] to reduce sedimentation by strengthening existing regulations, and to set goals concerning growth and development, education, public access, and governance.[109] In 1992, the signatories amended the prior agreement to reaffirm their commitment to the 40 percent nutrient reduction goal, set goals for miles of riparian buffers, set specific nutrient reduction goals for the Bay's major tributaries, and pledged to keep nutrients in the Bay at or below the level they were expected to reach in 2000.[110] In 2000, the signatories acknowledged that they had achieved the riparian buffer goal, but had not achieved the 40 percent nutrient reduction goal. In the Chesapeake Bay 2000 Agreement, the parties specified more than 100 new commitments organized in five focus areas: protecting and restoring the Bay's living resources, protecting and restoring vital habitats, improving water quality, managing lands soundly, and engaging individuals and local communities. The signatories restated the 40 percent nutrient reduction goal, setting the target date at 2010.[111]

In order to implement Chesapeake 2000, the signatory states are to use "tributary strategies," sets of tributary-specific nutrient

106. MD. DEP'T OF NATURAL RES., CHESAPEAKE 2000–THE RENEWED BAY AGREEMENT, http://dnrweb.dnr.state.md.us/bay/res_protect/c2k/progress.asp (last visited Feb. 3, 2006).

107. 1983 Chesapeake Bay Agreement, U.S.-D.C.-Md.-Pa.-Va.-Chesapeake Bay Comm'n, Dec. 9, 1983, *available at* http://www.chesapeakebay.net/pubs/1983ChesapeakeBay Agreement.pdf. The Chesapeake Bay Commission, one of the signatories, is a tri-state body representing the state legislators of Maryland, Pennsylvania and Virginia.

108. 1987 Chesapeake Bay Agreement, U.S.-D.C.-Md.-Pa.-Va.-Chesapeake Bay Comm'n, Dec. 15, 1987, *available at* http://www.chesapeakebay.net/pubs/1987ChesapeakeBay Agreement.pdf.

109. *Id.*

110. Chesapeake Bay Agreement: 1992 Amendments, U.S.-D.C.-Md.-Pa.-Va.-Chesapeake Bay Comm'n, Aug. 12, 1992, *available at* http://www.chesapeakebay.net/pubs/1992 ChesapeakeBay Amendments.pdf.

111. Chesapeake 2000 Bay Agreement, U.S.-D.C.-Md.-Pa.-Va.-Chesapeake Bay Comm'n, June 28, 2000, *available at* http://www.chesapeakebay.net/agreement.htm.

reduction targets and plans, to reduce the flow of nutrients to the Bay.[112] Maryland has completed strategies for its ten major tributaries and their watersheds.[113] The Maryland strategies specify sediment load allocations and reduction goals and nitrogen and phosphorus caps, as well as implementation strategies intended to achieve these levels. Progress on many of the state's objectives is measured using predicted pollution control efficiencies calculated using the Chesapeake Bay Program Watershed Model, which uses available scientific data to associate certain levels of nutrient reduction or water quality change with best management or conservation practices.[114] The Maryland Department of Natural Resources hosts a website that lists all the state's Bay Agreement commitments, the strategies and programs being used to address them, and a percentage rating for Maryland's progress toward each commitment. For some of the Bay Agreement commitments, the site also lists associated statistics that show how the percentages were developed.[115]

The experiences in Pennsylvania, New Jersey, and Maryland suggest that environmental indicators must be linked to identified management decisions if they are to affect programs. State laws define institutional jurisdiction, time periods for decisions, processing requirements, and the information upon which a decision must be based. These constraints mean that the mere availability of good scientific information is not necessarily sufficient to produce different decisions. Institutional capacities and limitations determine whether and to what extent scientific data can be used and interpreted by users within these decisional systems.

B. Spatial Relationship of Indicators to Decisions

Ecological, hydrological, or other geographical boundaries of areas characterized by environmental indicators usually do not correspond to jurisdictional boundaries for decisionmaking. Watersheds rarely correspond to counties or townships, and wildlife

112. *Id.*

113. MD. DEP'T OF NATURAL RES., TRIBUTARY STRATEGIES, http://www.dnr.state.md.us/bay/ tribstrat (last visited Feb. 3, 2006).

114. U.S. ENVTL. PROT. AGENCY, MODELING THE CHESAPEAKE BAY (Aug. 20, 2001), *available at* http://www.chesapeakebay.net/wqcmodeling.htm.

115. MD. DEP'T OF NATURAL RES., *supra* note 106.

populations are affected, throughout their life cycles, by activities in numerous jurisdictions. From a scientific perspective, it is necessary to determine whether indicators can be made available at the scale desired by the manager or whether the management decision can be assigned to an institutional decisional body whose jurisdiction corresponds more closely to the geographic scale of the available indicator. In short, can the indicator be tailored to the jurisdictional area of the decisionmaker, or can a jurisdictional entity be constructed to take advantage of the indicator?

The responses of natural resource managers to data are significantly dictated by the management structures within which they operate. The management structure greatly influences, and may even result in forcing, a decision based on the scale and characteristics of the decisionmaker rather than that of the resource. For example, if the resource focus is the recovery of a particular watershed, indicators must be made accessible to all of the institutional decisionmakers that have jurisdiction over the many constituent parts of the watershed. Indicators should also be available to entities whose larger geographic jurisdictions may encompass multiple watersheds, of which the subject watershed is only a part.

Often there are multiple decisionmakers with partial and overlapping jurisdiction in a given area of interest. For example, in the U.S. Geological Survey 11-digit HUC Spring Creek Watershed in Centre County, Pennsylvania, examined by the Atlantic Slope research effort, there are over 30 decisionmaking entities that correspond to the types of potential indicator users identified in the preceding section.[116] These are 14 townships and boroughs, the county, the Centre Regional Planning Agency, the Spring Creek Watershed Commission, the Spring Creek Watershed Community (a coordinating group), the Clear Water Conservancy (a nonprofit acting as fiscal agent for the Spring Creek Watershed Community), Trout Unlimited's Spring Creek Chapter, the Susquehanna River Basin Commission, the Centre County Conservation District, Pennsylvania Department of Transportation, University Area Joint Authority, Spring-Benner-Walker Joint Authority, State College

116. Kristen Saacke Blunke, Integrating Response Variables to Evaluate the Aquatic Condition of the Spring Creek Watershed, Centre County, Pennsylvania (May 2005) (unpublished Master's thesis, Penn State University School of Forest Resources) (on file with authors).

Borough Water Authority, College Township Water Authority, Pennsylvania Public Utilities Commission, Pennsylvania Department of Environmental Protection, Pennsylvania Game Commission, Pennsylvania Fish & Boat Commission, Pennsylvania Department of Conservation and Natural Resources, Pennsylvania Department of Community and Economic Development, and the Pennsylvania General Assembly. Also relevant is Pennsylvania State University, one of the largest institutional landowners and developers in the watershed.[117] Some of the institutions on this list, specifically the Spring Creek Watershed Community and Spring Creek Watershed Commission, were formed in order to create a forum that corresponds to the geography of the resource. However, neither organization is a decisionmaking body with legal or regulatory authority; rather, the two groups serve as places to direct research, consultation, and mutual persuasion among institutions that do have decisionmaking authority.[118]

In designing indicators and indicator systems, scientists and managers must understand the range of decision targets within the identified management structure in order to make the indicators useful at the right level of decisionmaking. Tailoring indicator systems to the varying needs and technical capacities of these diverse organizations is quite difficult. But presented with a complex jurisdictional system, designers of indicators risk irrelevance if they do not integrate the needs of end users into their functionally-oriented systems of describing and measuring change through environmental indicators.[119]

The other approach is to attempt to construct management structures that coincide with the relevant ecological scale of the resources affected by decisions. Fisheries management structure has to some degree applied science in responding both to resource needs based on aquatic organism life histories and changes in market forces and harvesting practices, which are often the sources of resource impacts. The evolution of the fisheries management structure as a resource-based jurisdiction proceeded in large part

117. *Id.*

118. For more information, *see* SPRING CREEK WATERSHED CMTY., http://www.springcreekwatershed.org (last visited Feb. 3, 2006), *and* CLEAR WATER CONSERVANCY, SPRING CREEK WATERSHED PLAN, http://www.clearwaterconservancy.org/watershed_plan.htm (last visited Feb. 3, 2006).

119. APPLYING ECOLOGICAL PRINCIPLES TO LAND MANAGEMENT at 1-12 (Virginia Dale & Richard Haeuber eds., Springer 2001).

because the management target was mobile, and it was easily demonstrated and communicated that the pressures on the resource transcended purely political boundaries.[120]

In the Atlantic Slope region, the development of the Atlantic States Marine Fisheries Commission (ASMFC) was based on recognition of harvest-based resource depletion and the acknowledgment of shared habitats. The Council on State Governments sponsored an Eastern States Conservation Conference in 1937 to discuss establishment of inter-jurisdictional management to ensure better use of fisheries resources, which led to the formation of the ASMFC by interstate compact in 1942. This was in direct response to the realization that applying state boundaries to larger-scale resources was a failed exercise. Subsequent evolution of the system of resource-defined jurisdictional limits with overlying federal authority has included interstate compacts that encourage cross-jurisdictional management, establishment of small-scale inter-jurisdictional "Common Conservation Zones," cross-jurisdictional enforcement agreements, inter-jurisdictional action committees, special area joint management commissions (for example, the Potomac River Fisheries Commission), multi-jurisdictional funding of large-scale research, and full resource-defined jurisdictional management.[121]

Since 1981, the authority for the ASMFC has been defined in the Interstate Fisheries Management Program, which requires the integration of science with decisionmaking.[122] The structure of the ASMFC has led to a continually evolving program capable of timely responses to observed changes in either the resource base or the social drivers of change. Although in an embryonic state, ASMFC's multi-species information and modeling initiatives will broaden the approach for species-targeted management by defining broad and innovative strategies that could be infeasible or ineffective under a geographically fractured management approach.[123] Multi-species

120. JOSH EAGLE ET AL., TAKING STOCK OF THE REGIONAL FISHERY MANAGEMENT COUNCILS at 8-11 (2003), *available at* http://fisheries.stanford.edu/Stanford_Council_Report.pdf.; Fisheries Conservation Management Act of 1976, Pub. L. No. 94-265, 90 Stat. 331 (1976).

121. ATL. STATES MARINE FISHERIES COMM'N, FIVE-YEAR STRATEGIC PLAN 2004–2008, at 2 (2003), *available at* http://www.asmfc.org/publications/asmfcStrategicfinal.pdf.

122. ATL. STATES MARINE FISHERIES COMM'N, INTERSTATE FISHERIES MANAGEMENT PROGRAM CHARTER (2002), *available at* http://www.asmfc.org/publications/isfmpCharter03.pdf.

123. *Id.*

management is only possible with a management structure that is strongly patterned on the resource.

In the Chesapeake Bay region, measures have been taken to set ecologically meaningful goals and measure progress using regionally-consistent indicators. The Chesapeake Bay Program, under successive multi-state and federal agreements, has been instrumental in promoting inter-jurisdictional cooperation for the management of living resources and water quality through data synthesis, communication, and education efforts.[124] Although no regulatory or enforcement authority is granted to this EPA program, inter-jurisdictional consistency is beneficial to the cooperating partners when addressing multi-jurisdictional resource issues. The Chesapeake Bay Program has been successful in prompting the cooperating jurisdictions to use a common metric for management purposes[125]

In general, it appears that either indicators must be tailored to existing geographical jurisdictions of the decisionmakers, or institutions must be created that correspond to the relevant ecological scale of the data. Because most indicators are measures of ecological conditions, or predictors of the effects of perturbation on a system, they are most readily usable in the context of ecologically defined geographic areas. That is, indicators tend to address the range of fish species, the aquatic health of the relevant watershed, the condition of the riparian zone, or the relevant physiographic region or bio-region. If the geographical jurisdiction of the decisionmaker is more limited than the area encompassed by the indicator, then some means must be found to disaggregate the indicator results, interpret the relevance of the results for the portion of the decision that is within the jurisdiction's authority, or seek consistency of action from multiple jurisdictions. These are all more difficult tasks than the creation and interpretation of an indicator that addresses itself to a fully competent decisionmaker with jurisdiction over the full area of the resource. This complexity of interpretation must be addressed explicitly by procedural and institutional choices if environmental indicators are to produce

124. For more information, *see* Chesapeake Bay Program, http://www.chesapeakebay.net (last visited Feb. 3, 2006).

125. CHESAPEAKE BAY PROGRAM & U.S. ENVTL. PROT. AGENCY, ENVIRONMENTAL OUTCOME-BASED MANAGEMENT: USING ENVIRONMENTAL GOALS AND MEASURES IN THE CHESAPEAKE BAY PROGRAM (1999), *available at* http://www.chesapeakebay.net/pubs/indpub/indpub.htm.

informed and effective decisions.

C. Process for Maintaining and Delivering Indicators

Selection of indicators requires not only the identification of relevant indicators that support real management decisions, but also the identification and support of institutions to collect, compile, and update the data that will support the indicators. There must be an apparatus to collect field data and/or integrate data collected by others, a means of compiling data and making comparisons across time and geography, and a plan for quality assurance. Institutional issues also include determining how the data will be maintained and updated, how corrections can be made, and how data will be made available to the intended users, which may include members of the general public. It is also necessary to be clear about the source or sponsorship of indicator information. For example, it may be politically easier for a local government official or body to rely upon indicator data collected pursuant to a state-sanctioned protocol, than to use superior methods or data that lack official recognition.

Confidence in both the validity and utility of indicators is increased when the processes for selecting the indicators and populating them with data are clearly articulated. Results can be reviewed by the public, interested parties, and academics. Counterintuitive results can be investigated and explicated. Moreover, public transparency builds support for reliance on indicators and for the funding and resources to maintain the system.

1. Policy Considerations

Developers of policy seeking to design robust indicator systems must understand the influences of time and space that affect the potential utility of environmental indicators. Significant external factors influence the effectiveness of indicators as decisionmaking tools. For example, is the information delivered to users in a form that can be understood? Is it focused on the right unit of application? Does its rate of change correspond to the rate of change relevant to the decisions it is meant to inform?

The differing rates of change of multi-scale components of an ecological and social system can influence the indicator's utility. Generally, there are considerable differences among the speed of social change, economic development, natural ecological processes, and science. All of these create discontinuities and inconsistencies that ultimately affect the ability of an environmental indicator to provide practical guidance. For instance, environmental indicator data on existing land cover in a watershed may be current. But the water chemistry data of recent years may have been influenced by lower-than-average precipitation, while the land development decisions anticipated in the next five years may portend a very fast rate of change, as, for example in Loudoun County, Virginia, which doubled in population in only ten years.[126]

An indicator's form and its focus of concern may also present variation. An indicator is essentially scientific information engineered into a particular structure that is more or less understandable to non-scientists. For example, its "form" may be an index of biological integrity (IBI), a weighted method of counting the existence and proportional share of living organisms, such as types of aquatic invertebrates, fish, or even birds, present in a given unit of water or land, which is used as a measure of ecological condition.[127] The indicator's "focus" can be defined as the ecological unit of application. The optimum situation occurs when form correlates with focus, when the indicator's interpretation of ecological condition is compatible with the relevant ecological scale, and when the data management system makes it possible to apply the indicator to the right decisional unit.[128] Some indicators are uniquely suited for small-scale environmental units such as headwaters trout streams, whereas others are best suited for large-scale watershed complexes. Application of indicators outside of the appropriate ecological scale may ultimately dilute the utility of the information and lead to ineffective policy development and implementation. Some person or institutional entity needs to be responsible for making sure that these scales and applications correspond, as indicators are typically not self-referencing.

It can be difficult to determine the most robust intersections of

126. LOUDOUN COUNTY, VA. BD. OF SUPERVISORS, COMPREHENSIVE PLAN 1-1 (2001), *available at* http://www.loudoun.gov/bos/docs/boscompplanrevi_/generalplan_/index.htm.

127. *E.g.*, NANCY ROTH, ET AL., BIOLOGICAL INDICATOR VARIABILITY AND STREAM MONITORING PROGRAM INTEGRATION: A MARYLAND CASE STUDY, EPA 9-03-R-02-008 (Jan. 2001), *available at* http://www.epa.gov/maia/pdf/bio_ind_md.pdf.

128. LESKA S. FORE, DEVELOPING BIOLOGICAL INDICATORS: LESSONS LEARNED FROM MID-ATLANTIC STREAMS, EPA 9-03-R-03-003 (Mar. 2003), *available at* http://www.epa.gov/ bioindicators/pdf/MAIA_lessons_learned_biology.pdf.

form and focus, particularly when attempting to determine the outer boundaries of these relationships. Some of the factors underlying these difficulties can be controlled and some can only be adapted to, but all should be recognized by the participating parties. Indicators cannot be treated simply as "black boxes" generating answers. If they are, the outputs will likely be misinterpreted while the necessary inputs may be allowed to degrade. Consultation of black box indicators may become exercises in interpretation of Delphic statements, or even worse, mere *pro forma* exercises satisfying a checkbox on a decision process. Instead, indicators must be understood as parts of *systems* intended to collect, package, and deliver relevant information within a larger decisional system.

2. Institutional Choices

Establishing a robust, continuing system of environmental indicators to support identified decisions by identified end users requires making some explicit institutional choices that support the delivery of indicator data and provide necessary interpretive support. Among the possible choices are: (1) designating a single entity to define the indicators and making it responsible for data collection, maintenance, update, and transmittal to others; (2) designating a single entity to define relevant indicators for each purpose and to aggregate data assembled primarily from other sources; (3) identifying separate agencies wholly responsible for each indicator type; or (4) providing an official endorsement of an approved indicator *methodology* to be used for designated purposes but leaving data collection and assembly up to individual users.[129]

Pennsylvania's EFP2 process had no single site or location for the indicator data, nor an institutional means for evaluating the proposed implementation approaches using the indicators. Each watershed team was responsible for identifying, selecting, and interpreting indicator information for its watershed. Watershed teams largely utilized data compiled by PADEP and other state agencies, but also looked to external sources of data such as educational institutions and citizen organizations. Some of the

129. A system using this fourth approach could, for example, designate the use of a particular index of biological integrity to determine watershed health, but would not itself be set up or funded to generate the indicator data that would inform decisions. That would be up to the users of the approved methodologies to do on a case-by-case basis as needed.

watershed teams did not have data for all 17 indicators or had only partial data for certain indicators, and several of the watershed teams took it upon themselves to develop monitoring efforts in order to obtain the desired data. In addition, EFP2 did not have its own central office, but was housed within PADEP's Policy Office. The 34 watershed teams do not have their own offices but meet as needed to perform their functions. Thus, there is no centralized or watershed-specific database of indicator data and trends; indicator data are collected when the teams gather to write their reports.

The action plans submitted by the 34 watershed teams caused a problem in the program given the unclear administrative structure. Some of the teams used the action plans as a type of comprehensive watershed management plan. Others organized their plans in a priority-setting manner in order to encourage PADEP to improve its strategic management. When this problem was recognized, state-level indicator expert teams were added to the process to review the watershed plans and suggest a unified format for future plans. Teams included personnel from the central PADEP office, regional offices, and advisors from outside agencies. Executive teams were directed to examine the action plans and to review the quality of the indicators, and their sources, that the watershed teams had identified. PADEP subsequently decided to conduct a review of the entire initiative.[130]

In New Jersey, in contrast with Pennsylvania, the NJDEP attempted to develop a defined suite of indicators for each DEP management objective in accordance with a cause-condition-response model.[131] The New Jersey Environmental Indicators Technical Report ("Report") provided "the technical basis, data sources and data limitations" for the indicators.[132] Indicators were categorized into eight areas: pollution/release prevention, global climate change, air quality/radiation, clean and plentiful water, land and natural resources, site remediation, solid/hazardous

130. Interviews by James M. McElfish, Jr. and Roman Czebiniak with Pennsylvania Department of Environmental Protection staff (2002–2003). *See also*, PA. DEP'T OF ENVTL. PROT., EFP2 SCHEDULE (2002), http://www.dep.state.pa.us/hosting/efp2/schedules/schedule.htm; PA. DEP'T OF ENVTL. PROT., EFP2 NEWS, http://www.dep.state.pa.us/hosting/efp2/information/news/news.htm (last visited Feb. 3, 2006).

131. N.J. DEP'T OF ENVTL. PROT. & U.S. ENVTL. PROT. AGENCY, *supra* note 93, at 16. Cause indicators represent stresses on the environment. Condition indicators represent ambient conditions such as ecological effects or human health. Response indicators represent societal (including regulatory) responses to the condition.

132. *Id.* at 29.

waste, and pesticides. Each indicator measured progress towards some specific milestone or objective, which itself was related to a particular "subgoal," a key environmental issue for the state. Each subgoal, in turn, related to a long term general goal for each environmental category. The Report provided the following information on each indicator: the milestone/objective to which it related, indicator title, type of indicator, what the indicator tells us, data characteristics, data strengths and weaknesses, and discussion of the indicator.[133]

New Jersey deemed it important to have ongoing academic participation in the indicator process to ensure rigor in identification and refinement of the indicators. This concern led NJDEP to establish the New Jersey Center for Environmental Indicators (NJCEI) in 1998.[134] NJCEI's Executive Committee consists of nine representatives from state government agencies, universities, and watershed associations. It meets bimonthly and is responsible for NJCEI's planning and development.[135] The Advisory Committee consists of eleven representatives from state and federal government agencies and commissions, universities, industry groups, and watershed associations. It provides NJCEI with guidance on its strategic planning and vision documents.[136] Finally, the Science and Technical Program Area Advisors review and provide recommendations for the NJCEI indicators in their area of expertise. There are two advisors for each of the six program areas: ozone, communication/outreach, air/greenhouse gases, water, human health and toxics, landscape/land use, and biodiversity/ecosystems.[137] The NJCEI was to review NJDEP's progress towards its strategic goals by examining the Department's Environmental Progress Briefings and identifying areas in need of indicator development and refinement.[138] NJDEP never developed a centralized database of indicator information. It was hoped that a regular process of reporting, from the particular divisions which

133. N.J. DEP'T OF ENVTL. PROT., NEW JERSEY ENVIRONMENTAL INDICATORS TECHNICAL REPORT (2d. ed. 2001), *available at* http://www.state.nj.us/dep/dsr/indicator-report.

134. N.J. Ctr. for Envtl. Indicators, *supra* note 11. The Environmental and Occupational Health Sciences Institute (EOHSI) is a joint institute of Rutgers University and University of Medicine and Dentistry in New Jersey (UMDNJ).

135. N.J. Ctr. for Envtl. Indicators, People, http://scc.rutgers.edu/cei/people/people_index.htm (last visited Feb. 3, 2006).

136. *Id.*

137. *Id.*

138. N.J. DEP'T OF ENVTL. PROT. & U.S. ENVTL. PROT. AGENCY, *supra* note 93, at 39.

gathered the information to the Steering Committee and indicator staff, would occur. But the program did not get to this point before being downsized by the subsequent administration.

Designers of institutional frameworks must be aware the trade-offs between choosing to track a greater number of indicators in a smaller number of geographic areas, or choosing to track a smaller number of indicators in a greater number of areas. Tracking hundreds of indicators statewide may be of some general value to a state legislature, but it is likely to have very low value to site-specific decisionmakers. Conversely, well-developed and detailed systems of only a few indicators are likely to be very worthwhile to local governments, regional bodies, and others operating in specific places, but not as useful to state wide decisionmakers.

The designers of these systems must determine how the indicators and data supporting these indicators are transmitted or made available to the intended users. In general, indicators that have some authoritative quality, *i.e.* an official endorsement by a state agency, are valuable for local governments,[139] and may be even more important in assuring use than a technically superior academically based system. The New Jersey system mixed authoritativeness with informational richness. The Pennsylvania system had no authoritativeness at all for its non-PADEP users, who were essentially all volunteers. In contrast, the official multi-state agreement to use the Chesapeake Bay model has had great influence on state and federal agency decisions, even though criticisms of the model and potential alternative systems have suggested that more data and less reliance on modeling might produce improved credibility for the management system.[140] Institutional designs for environmental indicator systems should seek consistently maintained, officially endorsed indicator systems, linked to identified management objectives.

139. *See* JAMES M. MCELFISH, JR., NATURE-FRIENDLY ORDINANCES 23–30 (2004) (providing information for local conservation benefits from state investments and provision of technical assistance to local units of government seeking to use information).

140. Peter Whoriskey, *Bay Pollution Progress Overstated: Government Program's Computer Model Proved Too Optimistic*, WASH. POST, Jul. 18, 2004, at A1; U.S. GOVERNMENT ACCOUNTABILITY OFFICE, CHESAPEAKE BAY PROGRAM: IMPROVED STRATEGIES ARE NEEDED TO BETTER ASSESS, REPORT, AND MANAGE RESTORATION PROGRESS, GAO-06-96 (October 2005), *available at* http://www.gao.gov/new.items/d0696.pdf.

III. CONCLUSIONS

This project has identified the practical challenges accompanying environmental indicator development and application by focusing on the decisionmakers expected to use these science-based tools. Experience with attempts to integrate environmental indicators and management decisions reveals challenges in both the products and the processes. They include inconsistent approaches within and among programs, lack of understanding of the missions and intents of the target user programs, and ill-defined roles for indicator providers and potential users. Understanding the characteristics of these systems can result in improvement of information systems. We propose a dual approach to future environmental indicator initiatives.

First, it is essential to establish clearly defined assignments of labor and responsibility for indicator systems in order to improve their effectiveness in influencing management decisions by the current set of potential users. As we found, capacity to deal with data collection and interpretation varies widely among institutions. Institutional users of environmental indicators range from the technically sophisticated to the unsupported generalist board. Key design issues include responsibility for indicator selection, data collection and maintenance, interpretation of the data, including the degree of authority such interpretation should have, and how environmental indicator information should flow from data compilers and interpreters to the decisionmakers. While growing pains are to be expected in continuing systems to develop and implement science-based information as an aid to public decisionmaking, assigning these key functions to institutions on the basis of their capacities will address many of the historical problems with environmental indicators in the existing systems.

Second, we can use environmental indicators to assist in a critical evaluation of potential alternative management structures. The focus of an environmental indicator can illuminate the functional boundaries of a resource that is to be managed. With few exceptions, management structures are Balkanized with respect to most resources. The scientific community has recognized that management structures have not kept pace with scientific advancements in understanding both the local and remote functions of aquatic resources. Environmental indicators systems offer the opportunity to answer the question of the appropriate management structure for a natural resource complex. The regional fisheries management structures and the regional, albeit limited, governance exercises in the Chesapeake Bay region with respect to aquatic resources suggest the potential value of creating or deriving management and decisionmaking institutions from the characteristics of the resources being measured.

In the past, environmental indicator systems have often been guided by the question: "what is the best resource condition?" It would also be prudent, and is now practicable, to address the question: "what is the best decisional or management unit for the resources of concern?"[141] It would be disappointing to construct indicator systems that generate valid results and then realize that implementation is impossible or problematic due to an incompatible management or decisional structure. Because of their resource focus and their potential to provide accountability for outcomes, environmental indicators systems offer a credible method for siting decisionmaking at the appropriate level and guiding the creation of new governance units, if needed, to address resources or issues of concern.

141. *See* Bradley C. Karkkainen, *Collaborative Ecosystem Governance: Scale, Complexity, and Dynamism*, 21 Va. Envtl. L.J. 189, 217–222 (2002) (proposing a transition to resource-defined governance units).